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PHOENIX - TUCSON METROPOLITAN AREA AIR POLLUTANT EMISSION INVENTORY

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A summary report is presented of the emission inventory for the Phoenix - Tucson Metropolitan Area. The report provides estimates of the present levels of air pollutant emissions and status of their control. The pollutants which include sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides are delineated with respect to source type, season of the year, and geographical distribution within the area. The Study Area, which consists of eight counties located in the southern part of the State of Arizona, is divided into grid zones that serve as the basis for locating sources and reporting their emissions. All sources of emissions were classified into the following categories: transportation, fuel combustion in stationary sources, solid-waste disposal, industrial process losses, organic solvent evaporation, and agricultural operations.

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Evaporation

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PHOENIX-TUCSON METROPOLITAN AREA

AIR POLLUTANT EMISSION INVENTORY

Clyde B. Morita

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration
Division of Air Quality and Emission Data
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1. Arizona State Department of Health
2. Maricopa County Health Department
3. Pima County Air Pollution Control District

PREFACE

This report, which presents the emission inventory of the Phoenix-Tucson metropolitan area, is another in a series of studies outlining the sources and emissions of air pollutants for major metropolitan areas in the country. These reports provide estimates of total emissions of oxides of sulfur, oxides of nitrogen, hydrocarbons, carbon monoxide and particulate matter. The emissions of these pollutants are delineated with respect to source type, season of the year, and by their geographical distribution within the area. These surveys are also intended to determine the present level of emissions and status of their control.

The general procedure for these surveys is based on the rapid survey technique.[1] The Study Area is divided into grid zones that serve as the basis for locating sources and reporting their emissions. All sources of pollutants are divided into two subgroups—point and area sources. Sources that emit large quantities of air pollutants are considered individually and located specifically within the area. This group generally contains about fifty to one hundred sources and typically includes large industries, power plants, and central refuse burning facilities. The remaining multitude of sources are considered collectively as area sources and their emissions are reported as totals for grid zones. This category includes motor vehicles, home heating, smaller industries, on-site refuse burning, etc.

Emissions for the most part are estimated using various indicators of pollutant emissions and average emission factors that are related to these. Information and data are collected on fuel consumption, refuse burning rates, vehicle miles of travel, as well as various production data. These are then translated into emission estimates by use of average emission factors.[2] These factors, for the most part, represent average emission rates for a particular industry or fuel type.

Because of the inherent difference in types of equipment, operating rates, control equipment, and efficiency of operation among the plants

and fuel users within a given category, the application of the emission factors to any individual plant or even a smaller number of similar plants or processes may result in a discrepancy between the actual and the estimated emissions. However, the estimates of total pollutants from all sources in the study area should be reasonably accurate since the emission factors are based on average conditions.

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INTRODUCTION

The information and data presented in this report were gathered in cooperation with the acknowledged State and local agencies during a survey conducted in November, 1968. The data obtained is for the most part representative of 1967 and the emission estimates presented herein should be considered as describing the levels and conditions during that year.

The purposes of this study are to establish the magnitude and sources of air pollutant emissions in this area for incorporation into a national emission baseline, and to use the emission estimates in a diffusion model to establish the relative extent of air pollution in the area. These data are used as the basis of the engineering evaluation in the designation of an air quality control region for the Phoenix-Tucson area.

SUMMARY OF RESULTS

The estimated annual emissions of the five surveyed pollutants in the Phoenix-Tucson metropolitan area are 2,068,000 tons of sulfur oxides, 34,300 tons of particulate matter, 535,000 tons of carbon monoxide, 125,000 tons of hydrocarbons, and 62,400 tons of oxides of nitrogen. The air pollution problem in the urbanized areas is mainly automotive in nature. However, in some of the rural areas, the eight copper smelters release thousands of tons of sulfur oxides daily. The pollution from the smelters is believed to affect portions of the metropolitan area at times.

The breakdown of pollutant emissions by source category is listed in Table 1. The following is a brief summary of pollutant emission and sources:

Sulfur Oxides — The predominant source of the more than 2 million tons of sulfur oxides emitted annually is the copper smelting industry. The eight smelters collectively emit 99.7 percent of the sulfur oxides. The contribution from all other sources is negligible.

Particulate Matter — The annual emissions of 34,300 tons of particulate matter are distributed between the various source types. Transportation sources account for 29 percent, industrial process losses 38 percent, and agricultural operations 16 percent of the total particulate matter emissions. An additional 17 percent is divided between stationary fuel combustion and solid waste disposal.

Carbon Monoxide — Motor vehicles contribute 94 percent of the 535,000 tons of carbon monoxide emitted annually. Other sources include solid waste disposal operations

TABLE 1 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE PHOENIX-TUCSON STUDY AREA, 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles					
Gasoline	2,100	2,800	500,000	68,700	30,000
Diesel	700	1,900	1,030	2,400	3,900
Aircraft	N	2,300	12,000	4,400	2,000
Railroads	1,100	2,900	1,600	3,700	2,700
Stationary Fuel* Combustion					
Industrial	770	2,000	1,060	2,400	5,100
Steam-Electric	10	290	N	N	7,500
Residential	70	230	25	5	1,300
Commercial-Institutional	150	300	120	290	1,300
Solid Waste Disposal					
Open Burning	N	3,000	15,900	5,700	2,040
Incineration	40	200	1,500	20	80
Industrial Process	2,062,000	13,000	360	N	1,000
Solvent Evaporation	--	--	--	35,500	--
Agriculture	1,480	5,400	980	2,200	5,500
TOTAL	2,068,000	34,300	535,000	125,000	62,400

N = Negligible

* Emissions from agricultural fuel combustion included in agriculture column.

and aircraft which account for 2 and 3 percent, respectively, of carbon monoxide emissions.

Hydrocarbons

The two largest sources of the 125,000 tons of hydrocarbon emitted are motor vehicles and organic solvent evaporation. They contribute 57 percent and 28 percent, respectively, of the total hydrocarbon emissions. Other transportation sources account for approximately 6 percent, solid waste disposal 5 percent, and other sources 4 percent of hydrocarbon emissions.

Oxides of Nitrogen

Motor vehicles contribute more than 55 percent of the total of 62,400 tons of nitrogen oxides emitted annually. Fuel combustion in stationary sources accounts for 25 percent of total nitrogen oxides with natural gas combustion accounting for about three-fourths of this total. Other contributing sources are agricultural operations at 9 percent, other transportation sources at 7 percent, and solid waste disposal and industrial processes collectively at 4 percent.

STUDY AREA

The Study Area for the Phoenix-Tucson Metropolitan Area Air Pollutant Emission Inventory consists of eight counties located in the southern part of the State of Arizona. In fact the Study Area includes 84 percent of the population and 37 percent of the land area of the State of Arizona. Figure 1 presents the Study Area in relation to the rest of the State.

The eight counties consist of the cities of Phoenix and Tucson and the following counties--Cochise, Gila, Graham, Greenlee, Maricopa, Pima, Pinal, and Santa Cruz. This area occupies 42,700 square miles and contains an estimated 1967 population of 1,390,000.[3] Most of the population (86 percent) lives in Maricopa and Pima Counties (see Table 2). This area has had a population increase of 25 percent from 1960 to 1967. This rate of increase is much higher than the national average and is probably due to the increasing popularity of this area as a tourist and retirement resort.

The Study Area contains two Standard Metropolitan Statistical Areas (SMSA) as defined by the Bureau of Budget. The Phoenix SMSA, which includes all of Maricopa County, and the Tucson SMSA, which includes all of Pima County, are the thirty-fourth and eighty-ninth largest (population wise) SMSA's, respectively, in this country. The remaining six counties were included in the Study Area primarily because of the existence of copper smelters in four of these six counties.

Topography and Climate

The Phoenix-Tucson area is a contrast between flat desert plains and rugged mountain ranges and jutting hills. Phoenix is located in the center of the Salt River Valley, a broad, oval-shaped, nearly flat plain. The Salt River runs from east to west through the valley, but because of impounding dams upstream, it is usually dry. Tucson, located southeast of Phoenix, is practically surrounded by mountains rising to an altitude of 4,000 to 6,000 feet.

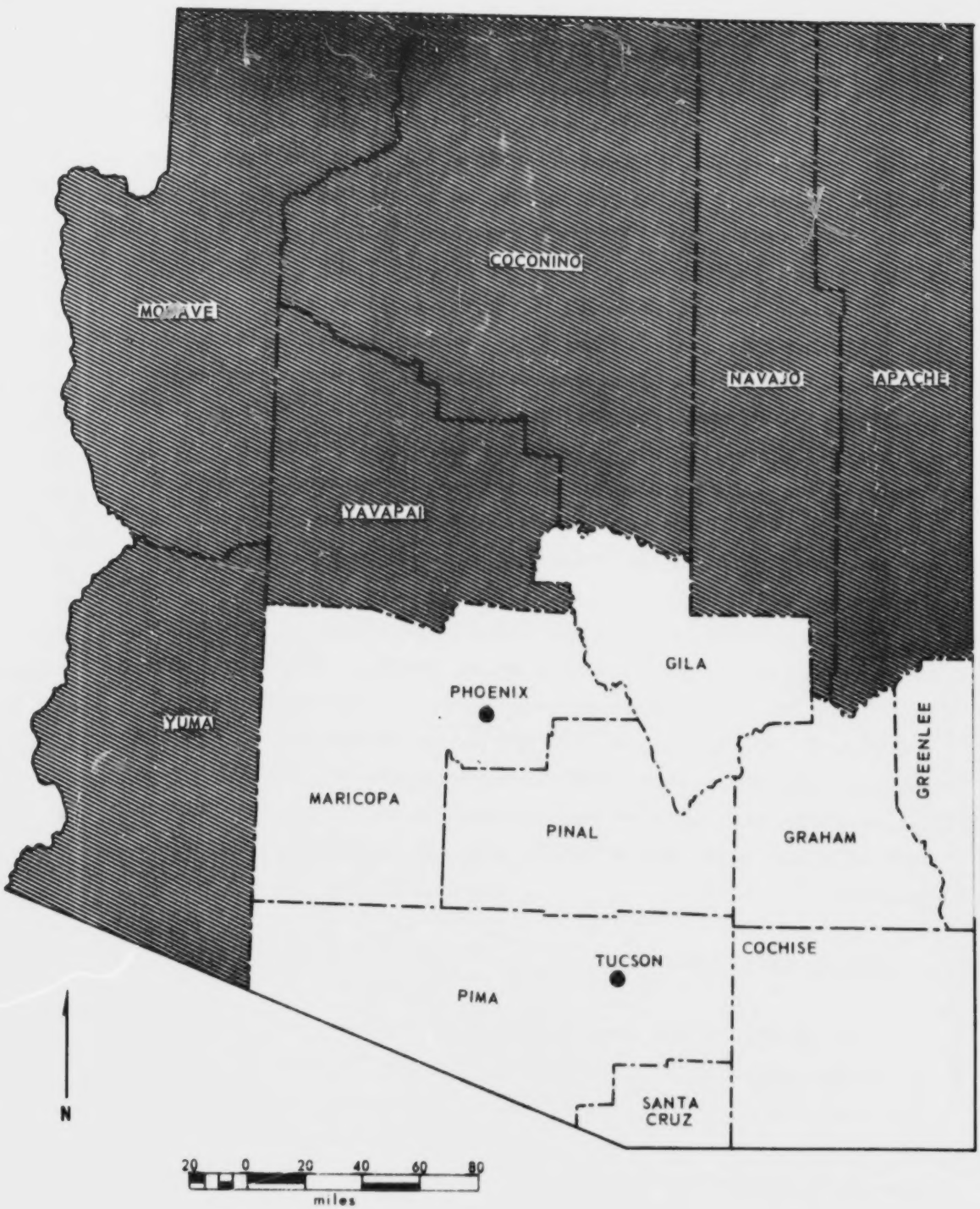

Figure 1. Location of the Phoenix-Tucson study area within the state of Arizona.

The climate of the area is characterized by a long hot season beginning in April and ending in October. Surface winds are generally light, with no important seasonal changes in either velocity or prevailing wind direction. The prevailing wind direction is easterly around Phoenix and southeasterly around Tucson.

Grid Coordinate System

For the purposes of this survey, the Study Area was divided into 67 grids. As shown on Figure 2, grids of 100, 400, 1600, and 6400 square kilometers were used to show the geographical distribution of sources and emissions. The grid system is based on the Universal Transverse Mercator System. The easting (east-west) and northing (north-south) coordinates are expressed in meters.

Different sizes of grids are used to limit the number of grid zones yet allow a satisfactory definition of the geographical gradation of emissions in areas where the majority of pollution occurs. For this reason, the smaller grids are used in the urban areas where emission densities tend to change abruptly within short distances. In areas primarily rural in nature, the use of small zones are not warranted.

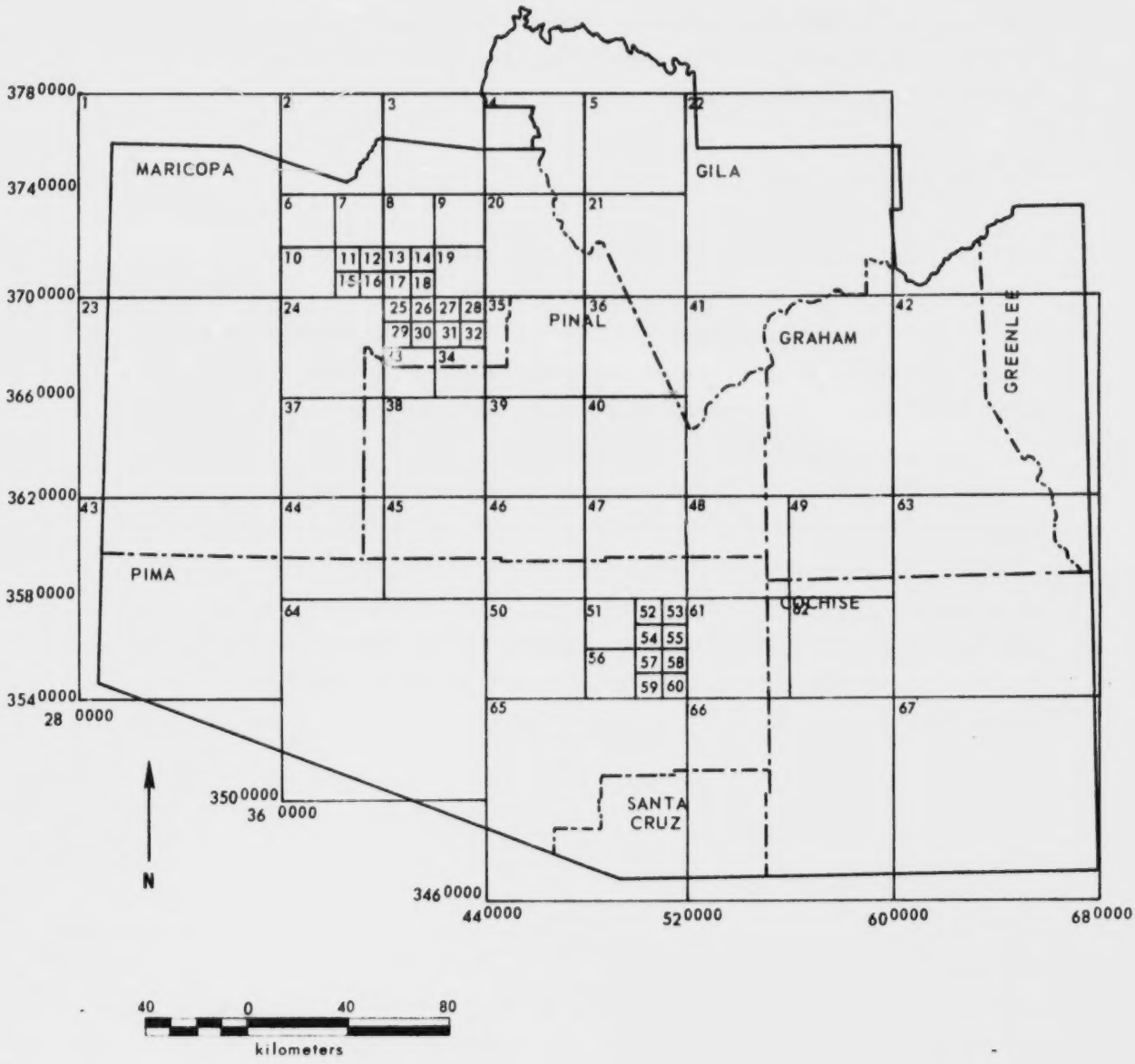

Figure 2. Grid coordinate system for the Phoenix-Tucson study area.

TABLE 2 POPULATION AND AREA CHARACTERISTICS FOR THE PHOENIX-TUCSON STUDY AREA, 1967

County	Land Area (sq. mi.)	1960 Population	1967 Population	1967 Population Density People/sq. mi.
Cochise	6,260	55,000	65,700	10.5
Gila	4,790	25,700	27,000	5.6
Graham	4,640	14,000	15,800	3.4
Greenlee	1,880	11,500	10,400	5.5
Maricopa	9,250	663,500	872,100	94.3
Pima	9.240	265,700	322,200	34.9
Pinal	5,390	62,700	64,000	11.9
Santa Cruz	1,250	10,800	14,000	11.2
TOTAL	42,700	1,110,000	1,390,000	32.5

TABLE 3 MOTOR FUEL CONSUMPTION AND VEHICLE-MILES OF TRAVEL, 1967

County	Gasoline Consumption (10^3 gallons)	Diesel Fuel Consumption (10^3 gallons)	Total Vehicle-Miles (10^6 Vehicle Miles/Yr.)
Cochise	24,200	2,690	360
Gila	12,700	1,410	190
Graham	6,300	700	90
Greenlee	3,000	340	45
Maricopa	337,800	18,600	4,520
Pima	108,600	6,100	1,630
Pinal	22,300	2,480	330
Santa Cruz	5,200	580	80
TOTAL	520,100	32,900	7,240

EMISSIONS BY SOURCE CATEGORY

For the purposes of compiling the basic data and emission estimates, the sources of air pollutants were classified into the following six categories:

1. Transportation
2. Fuel combustion in stationary sources
3. Solid wastes disposal
4. Industrial process losses
5. Organic solvent evaporation
6. Agriculture

Each of these categories are considered individually in this section. The data sources and necessary assumptions are presented with further breakdowns of emissions. Most of the estimates presented here are area-wide totals. The section on emissions by jurisdiction presents the emissions by source for every county.

The estimates presented herein, especially in the industrial process loss category, are for the most part partial totals. The lack of emission factors and appropriate process and control data prevent a complete inventory of all sources and emissions. However, the major sources have been included and the sources not considered should be negligible. The results should be viewed with these limitations.

Transportation

Three types of transportation sources are considered in this survey--motor vehicles, aircraft, and railroads. Motor vehicles, which are by far the most significant source of air pollution in this category are further subdivided according to type of fuel used--gasoline and diesel.

Motor Vehicles

More than 7.2 billion miles were traveled by motor vehicles in 1967. In the process, 520 million gallons of gasoline and 33 million

gallons of diesel fuel were consumed for highway purposes.[3] Table 3 indicates that about 85 percent of all motor vehicle travel occurs in Maricopa and Pima Counties.

Approximately 1.5 to 2.0 percent of gasoline is lost through evaporation from the gasoline tanks and carburetor losses resulting in annual losses of about 7.8 million gallons. It was assumed that no diesel fuel was lost by evaporation. Since 1963, most new automobiles were equipped with positive crankcase ventilation (PCV) valves that reduce hydrocarbon emissions from the crankcase by about 90 percent. Due to a lag time in the automobile replacement rate, it was assumed that only 20 percent of the automobiles were not equiped with PCV valves.

The vehicle miles of travel were apportioned onto the grids by the use of traffic information (vehicle miles and traffic flow maps) obtained from Arizona Highway Department.[4] This information was available for the urban portions of Maricopa and Pima Counties. Population was used as the basis of apportionment in the other counties. Appropriate speeds were assigned to each grid depending on the type of area, and emissions were calculated on the basis of speed and vehicle miles.

The resulting emissions from motor vehicles are shown on Table 4 along with emissions from other transportation sources. Motor vehicles are by far the most significant transportation source accounting for 72 percent of the sulfur oxides, 48 percent of the particulate matter, 97 percent of the carbon monoxide, 92 percent of the hydrocarbons, and 88 percent of the oxides of nitrogen emitted from transportation sources.

Aircraft

There are five major airports operating in the Study Area. Of these five, two are municipal airports, while the others are air force bases. Sky Harbor Airport is by far the busiest of the five airports. Collectively a total of 444,000 flights (take off and landing) were performed during 1967.[5,6,7]

Table 5 indicates that the Sky Harbor Airport is higher in emissions of carbon monoxide and hydrocarbons than the other airports, but Luke AFB emits the highest amounts of particulate matter and nitrogen oxides.

TABLE 4 AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES, 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Motor Vehicles					
Gasoline					
Exhaust	2,100	2,800	501,000	39,000	30,000
Evaporation	N	N	N	30,000	N
Diesel	700	1,950	1,070	2,400	3,900
TOTAL	2,800	4,800	502,000	71,400	33,400
Aircraft					
Jet	N	250	2,460	780	1,550
Turboprop	N	10	40	10	20
Piston	N	2,200	9,400	1,770	450
TOTAL	N	2,300	12,000	2,600	2,000
Railroads	1,090	2,920	1,610	3,150	2,670
TOTAL	1,090	2,920	1,610	3,150	2,670
GRAND TOTAL	3,900	10,000	515,600	77,200	38,100

N = Negligible

Although Luke AFB has only about a third of the flights as Sky Harbor Airport, there are more jet flights annually (for training purposes). Table 4 shows the contribution of jet, turboprop and piston aircraft to the total emissions from transportation sources.

Railroads

Railroad operations (mainly locomotive) consume about 42 million gallons of diesel fuel annually within the Phoenix-Tucson area. This quantity is about 25 percent more than the amount of diesel fuel consumed by motor vehicles. Diesel fuel consumption data were available for Maricopa and Pima Counties and estimated from state totals for the other counties.[6,7]

Railroad operations contribute approximately 8 percent of the total particulate matter emissions in the Study Area. They account for less than 4 percent of total emissions from any other pollutant.

Fuel Combustion in Stationary Sources

Although all of the three major fuels (coal, oil, and natural gas) and liquified petroleum gases are consumed within the Study Area, natural gas is the most important by far. In 1967, natural gas accounted for 104 trillion BTU's or approximately 86 percent of the total energy consumption. As shown on Table 6, 100 billion cubic feet of natural gas, 85 million gallons of distillate fuel oil, 2.9 million gallons of redisual fuel oil, 45 million gallons of liquified petroleum gases, and only 800 tons of coal were consumed in the Study Area.

For the purposes of this survey, fuel combustion in stationary sources has been divided into five user categories--residential, commercial-institutional, industrial, steam-electric utility, and agricultural. Fuel combustion in agricultural operations has been included here, however, the emissions are presented in the Agriculture Section of this report.

Natural gas is consumed to a large extent in all five consumer categories. Steam-electric utilities consume the largest amount with residential users consuming almost as much. Distillate fuel oil, mainly

TABLE 5 AIR POLLUTANT EMISSIONS FROM AIRCRAFT
1967, (TONS/YEAR)

Airport	Total Flights	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Sky Harbor	190,000	N	130	7,000	1,400	450
Tucson International	98,000	N	410	2,700	540	380
Luke AFB*	61,000	N	940	1,370	350	650
Williams AFB	58,000	N	490	510	150	330
Davis-Monthan AFB	38,000	N	300	420	120	210
TOTAL	444,000	N	2,270	12,000	2,560	2,020

N = Negligible

* Includes 3 separate facilities

TABLE 6 FUEL CONSUMPTION BY USER CATEGORY, 1967

User Category	Natural Gas 10^6 cu. ft.	Distillate Fuel Oil* 10^3 gal.	Residual Fuel Oil 10^3 gal.	Liquified Petroleum Gases 10^3 gal.	Coal Tons
Residential	22,800	2,300	--	31,000	800
Commercial-Institutional	13,300	2,500	450	5,000	N
Industrial	11,500	30,000	500	3,000	N
Steam-Electric	38,300	110	N	N	N
Agricultural	14,100	50,000	1,900	600	N
TOTAL	100,000	85,000	2,850	45,000	800
BTU's, 10^{12}	104	12	0.4	4.3	.02

N = Negligible

* Includes diesel fuel

diesel fuel, is consumed predominantly in industrial and agricultural operations. The diesel fuel is used to operate pumps, generators, construction equipment, and miscellaneous types of engines. A small amount of residual fuel oil is consumed in the Study Area. It is mainly used in agricultural operations. A significant amount of liquified petroleum gases (LPG) is used for heating purposes. Most of the LPG is used in residences and mobile trailer parks where natural gas lines are not available. Only about 800 tons of coal are consumed for residential heating pruposes, mainly in the more isolated sections of the Study Area.

There are seven steam-electric generating plants within the Study Area. These plants consume 38 percent of the natural gas and about 33 percent of the total energy consumption in the Study Area. The fuel combustion by plant is summarized in Table 7. There are no air pollution control systems on any of these plants.

Whereas the natural gas consumption data, which was obtained from the gas utility companies, is fairly accurate, the fuel oil, LPG, and coal data are rough approximations. These data were primarily extrapolated from state totals published by the Bureau of Mines.[8,9] The sulfur and ash contents of the fuels used in the Study Area are summarized in Table 8.

The emissions from fuel combustion in stationary sources were apportioned to the individual grids mainly by population. In Maricopa County, industrial and commercial-institutional emissions were apportioned on the basis of land use maps.[10]

The air pollutant emissions resulting from fuel combustion in stationary sources are summarized in Table 9. The combustion of distillate fuel oil, although providing only 10 percent of the energy imput, produces the majority of air pollutants from the combustion of fuels. Only in the case of oxides of nitrogen does natural gas supply about two-thirds of the emissions. Coal, residual fuel oil, and LPG produce an insignificant amount of emissions.

Fuel combustion in stationary sources contributes about 25 percent of total nitrogen oxides emissions in the Study Area. Otherwise, it is not a significant contributor to emissions of the other four pollutants surveyed. This is a result of the predominance of natural

TABLE 7 FUEL CONSUMPTION IN STEAM-ELECTRIC GENERATING PLANTS, 1967

Plant	County	Natural Gas 10^6 Cubic Feet	Distillate Fuel Oil 10^3 Gallons
Aqua Fria	Maricopa	11,729	84
Apache	Cochise	1,938	--
DeMoss-Petrie	Pima	1,152	--
Irvington	Pima	14,773	--
Kyrene	Maricopa	2,167	29
Ocotillo	Maricopa	5,405	--
Saquaro	Pinal	1,114	--
TOTAL		38,278	113

TABLE 8 ANALYSIS OF FUELS CONSUMED IN THE STUDY AREA

Fuel	Percent Sulfur*	Percent Ash*
Natural Gas	0.0008	N.A.
Distillate Fuel Oil	0.3	N.A.
Residual Fuel Oil	1.5	N.A.
Coal	0.6	8.0
Liquified Petroleum Gases	0.0008	N.A.

N.A. = Not Applicable
* = By weight

TABLE 9 AIR POLLUTANT EMISSIONS FROM STATIONARY FUEL COMBUSTION SOURCES, 1967 (TONS/YEAR)[a]

Fuel	User Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Coal	Residential	7	4	20	30	1
	Total	7	4	20	30	1
Distillate[b] Fuel Oil	Residential	50	7	1	1	12
	Commercial-Institutional	90	240	130	300	480
	Industrial	710	1,820	1,050	2,400	3,900
	Steam-Electric	N	N	N	N	N
	Total	850	2,070	1,180	2,700	4,390
Residual Fuel Oil	Commercial-Institutional	60	5	N	N	20
	Industrial	60	5	N	N	20
	Total	120	10	N	N	40
Liquified Petroleum Gases	Residential	N	10	N	N	70
	Commercial-Institutional	N	3	N	N	15
	Industrial	N	1	N	N	5
	Total	N	14	N	N	90
Natural Gas	Residential	3	210	3	N	1,320
	Commercial-Institutional	N	130	N	N	760
	Industrial	N	100	N	N	1,230
	Steam-Electric	10	290	N	N	7,500
	Total	13	730	3	N	10,800
GRAND TOTAL		1,000	2,800	1,200	2,700	15,300

N = Negligible

[a] Excludes emissions from agriculture

[b] Includes diesel fuel

gas as the source of heat and power.

Solid Wastes Disposal

More than 1.3 million tons of solid wastes are generated annually within the Study Area. The bulk of this refuse is disposed of by means of landfills at which no burning takes place (see Table 10). According to a comprehensive solid wastes disposal report, 690,000 tons of refuse are disposed of at five different landfills in Maricopa County.[11] Of these five landfills, only two were classified as "sanitary landfills" in 1967. The other three sites have since been converted to sanitary landfills. An additional 165,000 tons of refuse are disposed of at landfills in Pima County. There are no municipal incinerators in the Study Area, but about 90,000 tons are disposed of at on-site commercial, industrial, and residential incinerators.

Excluding Maricopa and Pima Counties, there is a lack of information on solid waste disposal sites in the Study Area. However, open burning is prevalent, and it was assumed that all refuse generated was disposed of by open burning. An average generation rate of 4.5 pounds per capita per day was used. Emissions from solid wastes disposal were apportioned on the basis of population.

As indicated in Table 11, solid waste disposal by open burning and on-site incineration contributes 40 tons of sulfur oxides, 3,200 tons of particulate matter, 17,400 tons of carbon-monoxide, 5,720 tons of hydrocarbons, and 2,140 tons of nitrogen oxides annually. The bulk of emissions from solid wastes disposal are attributable to open burning activities.

Industrial Process Losses

The Study Area is notably void of any heavy industrial complexes with the exception of the copper smelting industry. From an air pollution standpoint, the copper smelters, sand and gravel operations, and cotton ginning operations are the most significant industrial process sources of air pollutants. The industries that generate air pollutant emissions from their processes include 5 asphalt batching plants, a portland

TABLE 10 SOLID WASTES DISPOSAL BY JURISDICTION

1967, (TONS/YEAR)

County	Amount Generated	Landfill	Incineration	Open Burning
Cochise	51,000	N	N	51,000
Gila	26,000	N	N	26,000
Graham	13,000	N	N	13,000
Greenlee	10,000	N	N	10,000
Maricopa	895,000	690,000	80,000	125,000
Pima	260,000	165,000	10,000	85,000
Pinal	53,000	N	N	53,000
Santa Cruz	12,000	N	N	12,000
TOTAL	1,320,000	855,000	90,000	375,000

N = Negligible

TABLE 11 AIR POLLUTANT EMISSIONS FROM SOLID WASTE DISPOSAL, 1967 (TONS/YEAR)

County	Source	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Cochise	Open Burning	--	410	2,160	770	280
Gila	Open Burning	--	205	1,080	340	140
Graham	Open Burning	--	105	560	200	70
Greenlee	Open Burning	--	80	420	160	50
Maricopa	Open Burning	--	1,000	5,370	1,970	690
	Incineration	36	120	390	20	80
Pima	Open Burning	--	680	3,600	1,260	480
	Incineration	4	80	1,070	10	4
Pinal	Open Burning	--	430	2,270	810	290
Santa Cruz	Incineration	--	90	490	175	60
TOTAL		40	3,200	17,400	5,720	2,140

cement manufacturing plant, numerous cotton ginning operations, 8 copper smelters, 8 metal operations, 20 sand and gravel plants, 2 chemical plants, and a number of miscellaneous operations.

As is the case in any emission inventory, the lack of emission factors and process information for some industrial processes did not allow a complete estimation of process emissions. Most notably lacking are emission factors for particulate matter from copper smelting operations. Despite the fact that most of the smelters are equipped with electrostatic precipitators, significant quantities of dust and fumes are emitted. However, the lack of an emission factor prevented a quantitative analysis of particulate matter emissions from smelters.

The 5 asphalt batching plants produce about 860,000 tons per year of asphalt. The plants range in size from 120 to 1100 tons per day. The three largest plants are equipped with a combination of cyclones and wet scrubbers while the other two plants are uncontrolled.

A portland cement plant located in Pima County produces 1.8 million barrels of cement annually by the dry process. The kilns are equipped with electrostatic precipitators, and the rotary driers are equipped with fabric baghouses.

The State of Arizona leads the nation in copper production. All of the copper smelters located in Arizona are included in the Study Area. In 1967, the 8 copper smelters produced 502,000 tons of copper. This tonnage accounted for about 53 percent of the total U.S. production of copper.[3] Arizona's production would have been even higher except for an industry-wide strike from July, 1967, to March, 1968. All of the smelters use reverberatory furnaces and converters. Most of the plants are equipped with electrostatic precipitators for recovery purposes. In addition, about 94,000 tons per year of sulfuric acid is produced from a sulfur recovery plant located next to one of the smelters.

There are about 20 sand and gravel operations processing more than 2.3 million tons of aggregate per year. A few of the plants utilize wet scrubbers on the crushing units, but most are uncontrolled. In addition to the handling of aggregate, about 700,000 cubic yards of concrete are produced at the plants that contain ready-mix facilities.

There are 5 steel foundries and 3 non-ferrous foundries operating in the Study Area. About 170,000 tons of steel castings are produced annually. Most of the steel is produced in electric arc furnaces that are equipped with wet scrubbers or baghouses.

In 1967, 245,000 acres of land were devoted to the production of cotton in Arizona.[3] 90 percent of this acreage was located in the Study Area as shown on Table 12. At an annual yield of 901 pounds of cotton per acre, about 99,000 tons of cotton were produced in the Study Area. Cotton ginning operations are a large source of fires, lint and dust during the harvest months. Most of the gins are equipped with cyclones.

There are a couple of chemical plants in the Study Area. Among these are producers of sulfuric acid, nitric acid, ammonium nitrate, ammonia and nitroglycerin. The quantities of these chemicals produced is not significant.

There are a number of miscellaneous establishments in the Study Area that contribute a small amount to the total air pollutant emissions. They include a beet sugar processing plant, a brick manufacturing plant and a number of grain mills.

The various industries in the area were contacted for fuel use and process information. Much of these data were available in the State and local agencies' files. From this information, industrial process losses were determined with appropriate emission factors.[2]

Air pollutants from industrial process losses amount to 2,062,000 tons of suffur oxides, 13,000 tons of particulate matter and 1,000 tons of oxides of nitrogen. The emissions of carbon monoxide and hydrocarbons are negligible. The breakdown of air pollutant emissions by process types is shown on Table 13.

The copper smelting industry generated more than 2 million tons of sulfur oxides. The Study Area thus has one of the highest rates of sulfur oxides emissions in the nation. According to a recent NAPCA survey, an estimated 31 million tons of sulfur oxides are emitted annually by all sources in the nation.[12] Thus, the Study Area contains about 7 percent of the total emissions of sulfur oxides throughout the country.

TABLE 12 DISTRIBUTION OF CROP ACREAGE BY COUNTY, 1967 (ACRES)

County	Alfalfa	Citrus	Cotton	Grains	Vegetables	Total
Cochise	8,300	--	8,654	90,050	2,100	114,604
Gila	400	--	11	50	--	761
Graham	5,300	--	13,200	38,550	--	59,000
Greenlee	1,500	--	1,215	2,950	--	5,815
Maricopa	97,700	16,700	92,300	226,000	52,120	510,880
Pima	1,800	50	16,140	31,700	2,030	52,460
Pinal	21,000	380	87,400	99,000	7,090	222,270
Santa Cruz	800	--	120	1,000	--	2,420
STATE TOTAL	196,000	41,335	245,000	589,000	93,750	1,222,000

TABLE 13 AIR POLLUTANT EMISSIONS FROM INDUSTRIAL PROCESS SOURCES, 1967 (TONS/YEAR)

Source	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Asphalt Batching	N	620	N	N	N
Cement Manufacturing	N	450	N	N	260
Cotton Ginning	N	2,400	N	N	N
Copper Smelting	2,062,000	N.A.	N.A.	N.A.	N.A.
Grain Milling	N	950	N	N	N
Metal Operations	N	330	360	N	N
Sand and Gravel Operations	N	8,230	N	N	N
Other	290	N	N	N	730
TOTAL	2,062,000	13,000	360	N	1,000

N = Negligible

N.A. = Not available

The dust and fumes generated from sand and gravel operations accounts for about 60 percent of the particulate matter generated by industrial process losses. Cotton ginning operations contribute an additional 20 percent. The remainder of particulate emissions is generated by diverse sources.

Organic Solvent Evaporation

Hydrocarbons are emitted during the evaporation of organic solvents used for various purposes. For the purpose of this survey, hydrocarbon emissions from evaporation due to gasoline marketing and "cut-back" asphalt are included in this section also. Solvents are used for many miscellaneous purposes such as dry cleaning, painting, degreasing, printing, etc.

Solvent Use

The Maricopa County Health Department estimates the per capita solvent usage as 24.5 pounds of solvents per year in Maricopa County.[13] Of this total, 3.9 pounds are used for dry cleaning, 8.1 pounds are used for surface coating operations (including painting), and 12.5 pounds are used for industrial and other domestic uses. Using these values but adjusting the per capita consumption of solvents for industrial uses by the ratio of manufacturing employment for the other counties, the resulting hydrocarbon emissions are shown on Table 14. It was assumed that all solvents used are eventually emitted into the air by evaporation.

Gasoline Marketing

There are four major points (excluding evaporation from the motor vehicle) of hydrocarbon emissions in the storage and handling of gasoline. They are:

1. Breathing and filling losses from storage tanks.
2. Filling losses from loading tank conveyances.
3. Filling losses from loading underground storage tanks at service stations.
4. Spillage and filling losses in filling automobile gas tanks at service stations.

Based on estimates of gasoline marketing losses from the Maricopa County Health Department, it is estimated that about 0.8 percent of the 520 million gallons consumed is lost by evaporation.[13] The resulting hydrocarbon emissions by county are shown on Table 14.

Asphalt-"Cutback"

The yearly use of cutback asphalt for the Study Area amounts to about 25,000 tons annually. About half of this total was used for road in Maricopa County. Assuming that the volatile solvent used is 30 percent of the cutback asphalt and 95 percent of the solvents are eventually airborne, 7,200 tons per year of hydrocarbons are emitted (see Table 14).

Agriculture

Agriculture is an important aspect of Arizona's economy. The value of agricultural crops in 1967 was estimated at 273 million dollars. Agricultural operations can be a significant contributor to air pollution, especially during the harvest season.

Among the operations that can contribute significant amounts of emissions are: the burning of brush, crops, and fields; the application of pesticides by aircraft; and the combustion of fuels to operate farm machinery. In this survey, only the latter two categories were considered.

Pesticide Application

An estimate of particulate emissions from the aircraft spraying of pesticides was available for Maricopa County.[13] Emissions for the other counties were estimated by proportioning the crop acreage by county to the Maricopa County statistics. The resulting emissions are 3,300 tons of particulate matter in 1967.

Combustion of Fuels

From the data listed in the previous sections, 14.1 billion cubic feet of natural gas, 50 million gallons of distillate fuel oil, 1.9 million gallons of residual fuel oil, and 6 million gallons of liquified petroleum gases were consumed for agricultural operations.

TABLE 14 SUMMARY OF HYDROCARBON EMISSIONS FROM ORGANIC SOLVENT EVAPORATION, 1967 (TONS/YEAR)

County	Solvent Use	Gasoline Marketing	Asphalt (Cut-back)	TOTAL
Cochise	620	620	870	2,100
Gila	260	320	390	970
Graham	130	160	220	510
Greenlee	70	80	90	240
Maricopa	10,900	7,750	3,320	22,000
Pima	3,150	2,790	1,100	7,040
Pinal	590	570	1,040	2,200
Santa Cruz	100	130	190	420
TOTAL	15,800	12,400	7,200	35,500

TABLE 15 AIR POLLUTANT EMISSIONS FROM AGRICULTURAL OPERATIONS, 1967 (TONS/YEAR)

Source	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Fuel Combustion					
Distillate Fuel Oil	1,240	1,960	980	2,200	4,620
Residual Fuel Oil	240	20	N	N	70
Natural Gas	N	130	N	N	810
Liquified Petroleum Gas	N	5	N	N	20
Pesticide Application	N	3,300	N	N	N
TOTAL	1,480	5,400	980	2,200	5,520

N = Negligible

Most of this fuel was used to operate farm machinery such as tractors, pumps, generators, and harvesting equipment.

A summary of emissions from agricultural operations is presented in Table 15. The maximum contribution to any pollutant is 15 percent of the total emissions of particulate matter. This percentage is somewhat higher during the harvest months when there is an increase in agricultural activities.

EMISSIONS BY JURISDICTION

The previous section presents the emissions by source category and, in some cases, by jurisdiction. The emissions by county and source are summarized here in Tables 16 through 19. Table 16, Table 17, and Table 18 show the emissions in Maricopa, Pima, and Pinal Counties, respectively. The emissions are shown for the remaining five counties collectively in Table 19.

As is expected due to a higher degree of urbanization than the other counties, Maricopa County and Pima County contribute the majority of air pollutants with the exception of sulfur oxides. As shown on Table 20, Maricopa County contributes a minumum of 40 percent of any pollutant and Pima County contributes a minumum of 22 percent of any pollutant (excepting sulfur oxides). On the other hand, Maricopa and Pima Counties, collectively, account for only 8 percent of total sulfur oxides emissions. Naturally, the reason Cochise, Gila, Greenlee, and Pinal Counties account for 92 percent of the sulfur oxides emissions is because seven of the eight copper smelters are located in those counties.

TABLE 16 SUMMARY OF AIR POLLUTANT EMISSIONS IN MARICOPA COUNTY, 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	1,700	2,790	321,600	44,800	21,000
Other	120	1,870	9,020	4,040	2,060
Total	1,820	4,660	330,600	48,800	23,100
Fuel Combustion in Stationary Sources					
Industrial	90	240	130	300	1,310
Steam-Electric	10	150	N	N	3,760
Residential	40	140	15	3	810
Commercial-Institutional	10	30	15	40	520
Total	150	560	160	340	6,400
Solid Waste Disposal	40	1,120	5,760	1,990	770
Industrial Process	290	5,090	310	N	N
Solvent Evaporation	N	N	N	22,000	N
Agriculture	140	2,220	200	460	1,160
GRAND TOTAL	2,400	13,700	337,000	73,600	31,400

N = Negligible

TABLE 17 SUMMARY OF AIR POLLUTANT EMISSIONS IN PIMA COUNTY, 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	630	1,040	111,700	15,900	7,590
Other	150	1,110	3,310	1,280	1,400
Total	780	2,150	115,000	17,200	9,000
Fuel Combustion in Stationary Sources					
Industrial	440	1,170	630	1,420	2,640
Steam-Electric	3	120	N	N	3,110
Residential	15	60	4	N	360
Commercial-Institutional	80	170	70	160	500
Total	540	1,520	700	1,580	6,610
Solid Waste Disposal	4	760	4,670	1,270	480
Industrial Process	154,000	6,780	50	N	260
Solvent Evaporation	N	N	N	7,040	N
Agriculture	230	370	130	290	710
GRAND TOTAL	155,500	11,600	121,000	27,400	17,100

N = Negligible

TABLE 18 SUMMARY OF AIR POLLUTANT EMISSIONS IN PINAL COUNTY, 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Transportion					
Motor Vehicles	150	270	20,400	3,130	1,630
Other	180	490	270	610	270
Total	330	760	20,700	3,740	1,900
Fuel Combustion in Stationary Sources					
Industrial	80	190	100	230	430
Steam-Electric	N	10	N	N	220
Residential	5	10	N	N	60
Commercial-Institutional	20	30	10	30	90
Total	110	240	110	260	800
Solid Waste Disposal	N	430	2,270	810	290
Industrial Process	303,000	920	N	N	N
Solvent Evaporation	N	N	N	2,200	N
Agriculture	600	1,540	350	780	2,010
GRAND TOTAL	304,000	3,900	23,400	7,800	5,000

N = Negligible

TABLE 19 SUMMARY OF AIR POLLUTANT EMISSIONS IN FIVE-COUNTY AREA,* 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	320	600	47,300	7,300	3,700
Other	650	1,730	1,000	1,170	970
Total	970	2,330	48,300	8,500	4,700
Fuel Combustion in Stationary Sources					
Industrial	160	400	200	450	720
Steam-Electric	N	10	N	N	410
Residential	10	20	5	N	70
Commercial-Institutional	40	70	20	60	190
Total	210	500	220	510	1,400
Solid Waste Disposal	N	890	4,700	1,650	580
Industrial Process	1,604,000	210	N	N	740
Solvent Evaporation	N	N	N	4,300	N
Agriculture	510	1,270	300	670	1,620
GRAND TOTAL	1,605,000	5,200	54,000	15,600	9,000

N = Negligible

* Cochise, Gila, Graham, Greenlee, and Santa Cruz Counties

TABLE 20 RELATIVE CONTRIBUTION OF EACH COUNTY TO TOTAL AIR POLLUTANT EMISSIONS, (PERCENT)

County	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Cochise	27	7	5	6	8
Gila	30	3	2	3	3
Graham	N	4	1	2	2
Greenlee	20	1	1	1	1
Maricopa	N	40	63	59	50
Pima	8	33	23	22	27
Pinal	15	11	4	6	8
Santa Cruz	N	1	1	1	1

N = Negligible

EMISSIONS BY GRID

For the purpose of defining the geographical variation of air pollutant emissions in the Study Area, the resulting emissions were apportioned on the grid coordinate system. The emissions were divided into two source groups--point and area sources. Twenty-nine point sources are identified individually with respect to location and emissions. Each of these point sources emits more than 1 ton per day of any pollutant.

Contribution of Point Sources

Figure 3 shows the location of all point sources in the area. Collectively the twenty-nine point sources account for 99.7 percent of sulfur oxides, 32 percent of particulate matter, 16 percent of nitrogen oxides, and only 2 percent of carbon monoxide and 2 percent of hydrocarbon emissions. The percent contribution to carbon monoxide emissions is low because motor vehicles, which are area sources contribute 94 percent of total carbon monoxide emissions. Similarly, the contribution to total hydrocarbon emissions is low since two groups of area sources, motor vehicles and organic solvent evaporation, are the major contributors. Table 21 presents the emissions of point sources. It is assumed that the seasonal variations in point source emissions are negligible.

Area sources are sources of emissions that are insignificant by themselves, but as a group emit a significant amount. Examples of area sources are motor vehicles, residences, light commercial and industrial establishments, and backyard burning. The emissions from area sources have been added to that for point sources to obtain total emissions by grid as shown on Table 22.

The emissions are presented for an annual average day, an average winter (December, January, February) day, and an average summer (June, July, August) day. The annual average daily emission rates were obtained by dividing yearly totals by 365 days per year. Seasonal averages were calculated by the use of space heating variations in fuel consumption and variations in motor vehicular traffic activity. Other sources were assumed to be constant throughout the year.

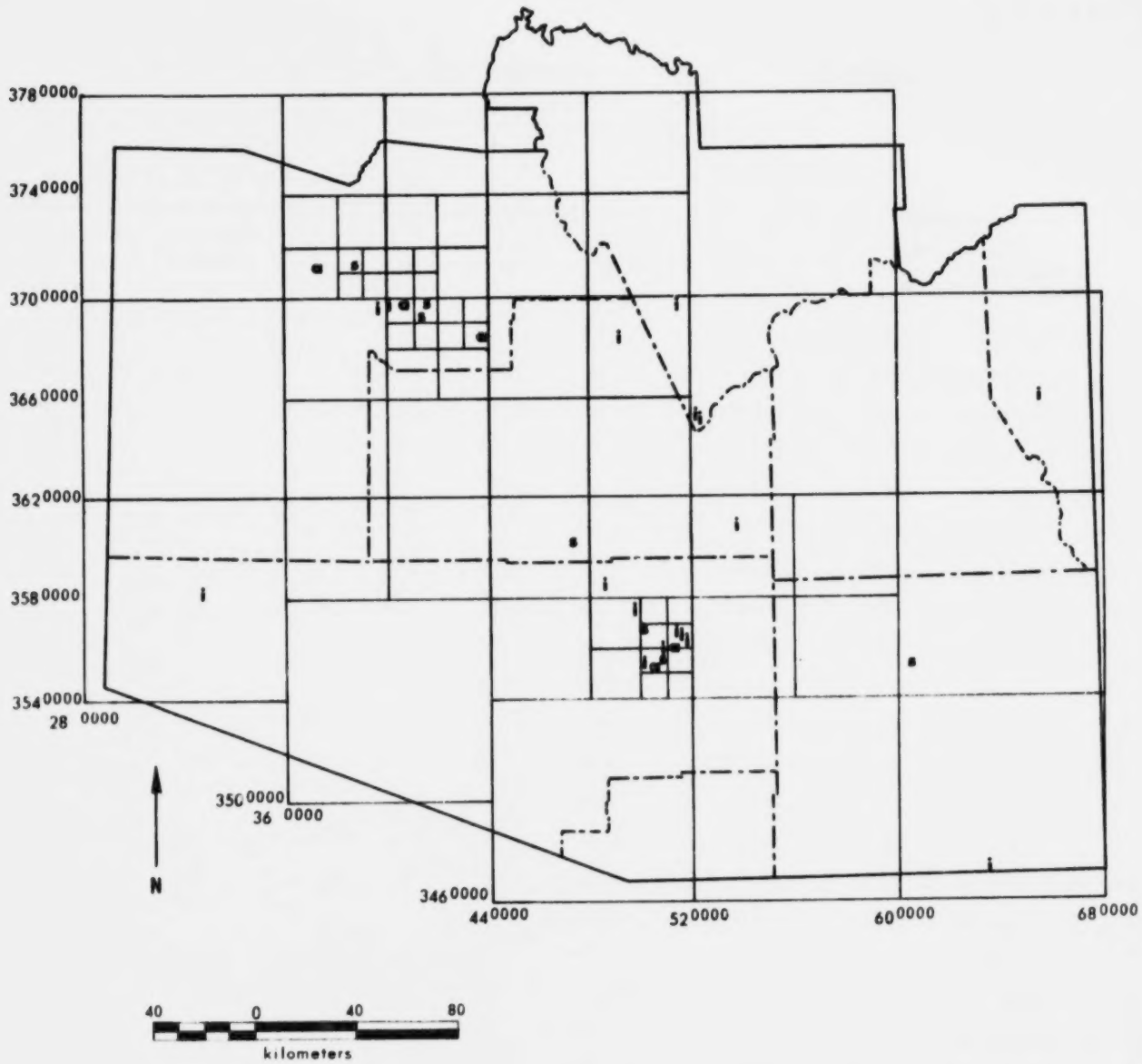

Figure 3. Location of point sources in the Phoenix-Tucson area

i industry

▪ steam-electric utility

▫ airport

TABLE 21 SUMMARY OF EMISSIONS FROM POINT SOURCES IN THE PHOENIX-TUCSON AREA, (TONS/AVERAGE DAY)

Source	Easting (100 m.)	Northing (100 m.)	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro Carbons	Nitrogen Oxides
Industry	4862	35860	--	1.23	--	--	0.72
Industry	5012	35549	--	2.50	--	--	--
Industry	5168	35627	--	2.50	--	--	--
Industry	5095	35585	--	2.13	--	--	--
Industry	5156	35658	--	3.97	--	--	--
Industry	4985	35745	--	3.30	--	--	--
Industry	5315	35678	--	1.50	--	--	--
Industry	4000	36980	--	3.06	--	--	--
Industry	3977	36974	--	2.41	--	--	--
Industry	3260	35820	420	--	--	--	--
Industry	6360	34680	1520	--	--	--	--
Industry	6550	36590	1150	--	--	--	--
Industry	5215	36520	560	--	--	--	--
Industry	5205	36525	610	--	--	--	--
Industry	5130	36975	450	--	--	--	--
Industry	5360	36080	650	--	--	--	--
Industry	4920	36830	180	--	--	--	--
Power Plant	6050	35530	--	.04	--	--	1.04
Power Plant	4153	36982	--	.11	--	--	2.89
Power Plant	4130	36910	--	.05	--	--	1.15
Power Plant	3872	37132	--	.27	--	--	6.28
Power Plant	4720	36020	--	.02	--	--	0.60
Power Plant	5095	35582	--	.30	--	--	7.88
Power Plant	5008	35680	--	.02	--	--	0.62
Airport	4060	36980	--	.35	19.10	3.85	1.22
Airport	3720	37120	--	2.57	3.75	0.96	1.79
Airport	4380	36850	--	1.35	1.39	0.40	0.91
Airport	5050	35540	--	1.12	7.31	1.47	1.05
Airport	5110	35600	--	.82	1.14	0.32	0.57

TABLE 22 SUMMARY OF EMISSIONS BY GRID IN THE PHOENIX-TUCSON AREA, 1967 (TONS/DAY)

Grid	Easting (100 m.)	Northing (100 m.)	Area (sq. mi)	SOx			PART.			CO			HC			NOx		
				S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
1	3200	37400	2471	.24	.23	.23	1.03	.99	1.02	32.62	29.84	31.08	5.55	5.13	4.71	2.50	2.34	2.40
2	3800	37600	618	.05	.05	.05	.08	.07	.07	8.11	7.42	7.73	1.29	1.18	1.23	.61	.56	.58
3	4200	37600	618	.06	.06	.06	.10	.09	.09	8.16	7.47	7.78	1.45	1.34	1.39	.63	.59	.61
4	4600	37600	618	.09	.08	.08	.18	.18	.18	10.10	9.27	9.64	1.93	1.80	1.86	.82	.78	.79
5	5000	37600	618	.01	.01	.01	.05	.05	.05	1.80	1.66	1.72	.31	.29	.30	.15	.15	.15
6	3700	37300	154	.20	.19	.20	.29	.28	.28	24.50	22.41	23.34	4.47	4.15	4.29	1.92	1.81	1.85
7	3900	37300	154	.12	.12	.12	.49	.71	.65	16.31	14.92	15.54	2.88	2.67	2.76	1.27	1.19	1.22
8	4100	37300	154	.13	.14	.13	.52	.52	.52	8.34	7.65	7.96	2.37	2.26	2.31	.77	.78	.76
9	4300	37300	154	.07	.07	.07	.37	.37	.37	8.19	7.50	7.81	1.66	1.55	1.60	.66	.64	.64
10	3700	37100	154	.26	.26	.26	3.56	4.13	3.65	28.43	26.33	27.26	6.11	5.79	5.93	3.81	3.74	3.75
11	3850	37150	39	.22	.22	.22	.52	.52	.52	16.55	15.27	15.78	4.14	3.93	4.02	7.73	7.70	7.72
12	3950	37150	39	.57	.56	.57	.61	.98	.88	28.77	26.41	27.46	9.44	9.11	9.26	2.62	2.80	2.66
13	4050	37150	39	.31	.30	.31	.38	.38	.38	28.05	25.69	26.74	6.09	5.76	5.90	2.12	2.10	2.09
14	4150	37150	39	.07	.07	.07	.11	.10	.11	8.19	7.50	7.81	1.66	1.55	1.60	.66	.64	.63
15	3850	37050	39	.15	.15	.15	.21	.20	.20	18.53	16.95	17.65	3.38	3.16	3.26	1.32	1.26	1.28
16	3950	37050	39	1.14	1.10	1.12	1.76	1.79	1.76	97.76	89.54	93.19	21.31	20.22	20.79	6.72	6.78	6.65
17	4050	37050	39	1.98	1.93	1.95	1.56	2.64	2.55	142.11	130.25	135.52	34.98	33.44	34.12	10.33	10.66	10.32
18	4150	37050	39	.50	.50	.50	.50	.53	.51	19.50	17.93	18.63	7.87	7.65	7.75	1.97	2.18	2.02
19	4300	37100	154	.16	.16	.16	1.46	1.45	1.46	16.38	14.99	15.61	3.32	3.11	3.20	1.33	1.28	1.29
20	4600	37200	618	.13	.20	.15	.19	.20	.19	14.66	13.44	13.97	2.77	2.58	2.66	1.26	1.18	1.21
21	5000	37200	618	.14	.22	.17	.28	.29	.28	11.28	10.40	10.79	2.69	2.60	2.62	1.05	1.03	1.03
22	5600	37400	2471	.08	.07	.07	.18	.17	.17	8.59	7.88	8.19	1.57	1.46	1.51	.73	.68	.70

TABLE 22 SUMMARY OF EMISSIONS BY GRID (cont.)

Grid	Easting (100 m.)	Northing (100 m.)	Area (sq. mi.)	SOx			PART.			CO			HC			NOx		
				S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
23	3200	36600	2471	.16	.16	.16	2.19	2.86	2.70	16.38	15.00	15.61	3.22	3.11	3.20	1.33	1.28	1.29
24	3800	36800	618	.45	.47	.46	4.51	5.09	4.93	25.15	23.08	24.00	7.66	7.35	7.49	2.38	2.46	2.38
25	4050	36950	39	1.03	.99	1.01	5.69	5.70	5.68	103.43	96.34	99.49	22.87	21.90	22.34	7.73	7.70	7.63
26	4150	36950	39	.64	.61	.62	1.40	1.39	1.39	75.33	68.94	71.78	13.47	12.65	13.01	8.81	8.68	8.69
27	4250	36950	39	.71	.68	.69	.91	1.00	.98	85.98	78.68	81.92	15.14	14.19	14.61	5.41	5.24	5.28
28	4350	36950	39	.09	.09	.09	.12	.35	.29	9.34	8.55	8.90	1.89	1.78	1.83	.69	.68	.68
29	4050	36850	39	.11	.11	.11	.19	.18	.18	16.30	14.91	15.53	2.75	2.54	2.63	1.24	1.16	1.19
30	4150	36850	39	.12	.12	.12	.19	.18	.18	16.31	14.92	15.54	2.88	2.67	2.82	1.27	1.19	1.22
31	4250	36850	39	.96	.96	.96	.22	.45	.38	18.53	16.95	17.65	3.51	3.29	3.39	1.36	1.28	1.29
32	4350	36850	39	.15	.15	.15	1.56	1.66	1.65	19.94	18.34	18.94	3.78	3.56	3.66	2.23	2.17	2.19
33	4100	36700	154	.07	.07	.07	.42	.42	.42	9.42	8.62	8.98	1.63	1.51	1.57	.73	.69	.70
34	4300	36700	154	.13	.12	.13	.60	1.15	1.02	11.84	10.86	11.30	2.64	2.48	2.55	1.11	1.07	1.08
35	4600	36800	618	.13	.12	.13	.64	1.37	1.20	11.84	10.86	11.30	2.64	2.48	2.55	1.11	1.07	1.08
36	5000	36800	618	630.00	630.00	630.00	.46	.45	.45	19.04	17.52	18.19	3.96	3.74	3.84	1.56	1.51	1.52
37	3800	36400	618	.07	.07	.07	.11	.10	.11	7.37	6.74	7.02	1.60	1.50	1.55	.66	.63	.64
38	4200	36400	618	.17	.16	.16	.41	1.21	1.02	15.07	13.90	14.41	3.41	3.23	3.31	1.37	1.33	1.33
39	4600	36400	618	.15	.16	.15	.38	1.45	1.17	10.45	9.66	10.01	2.90	2.78	2.83	.95	.96	.94
40	5000	36400	618	.05	.05	.05	.13	.14	.13	3.40	3.16	3.27	.98	.94	.96	.33	.33	.33
41	5600	36600	2471	1170.0	1170.0	1170.00	.56	.56	.56	16.30	15.07	15.61	4.13	3.94	4.03	1.56	1.55	1.53
42	6400	36600	2471	1150.0	1150.0	1150.00	.68	1.19	1.07	23.16	21.36	22.16	5.52	5.26	5.38	2.00	1.99	1.97
43	3200	35800	2471	420.00	420.00	420.00	.32	.32	.33	29.38	26.88	27.99	5.23	4.86	5.02	2.29	2.16	2.21
44	3800	36000	618	.08	.10	.09	.14	.13	.13	10.00	9.16	9.53	1.81	1.68	1.74	.84	.78	.80
45	4200	36000	618	.04	.06	.05	.10	.10	.10	4.38	4.04	4.19	.97	.92	.95	.38	.37	.37

TABLE 22 SUMMARY OF EMISSIONS BY GRID (cont.)

Grid	Easting (100 m.)	Northing (100 m.)	Area (sq. mi.)	S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
46	4600	36000	618	.14	.14	.13	.29	1.69	1.36	16.07	14.73	15.33	3.07	2.85	2.95	2.03	1.94	1.98
47	5000	36000	618	.12	.11	.11	1.57	1.62	1.57	13.28	12.16	12.66	2.57	2.39	2.47	1.90	1.83	1.95
48	5400	36000	618	650.00	650.00	650.00	.23	.23	.23	8.59	7.91	8.21	2.04	1.94	1.99	.71	.70	.70
49	5800	36000	618	.01	.01	.01	.03	.03	.03	.80	.74	.77	.27	.26	.26	.07	.07	.07
50	4600	35600	618	.06	.06	.06	.08	.07	.07	5.90	5.40	5.62	1.18	1.11	1.14	.47	.46	.46
51	4900	35700	154	.16	.15	.15	3.49	3.48	3.48	13.28	12.16	12.66	2.91	2.73	2.81	1.19	1.16	1.16
52	5050	35750	39	.18	.18	.19	.24	.24	.24	14.89	13.64	14.20	3.43	3.24	3.33	1.26	1.26	1.24
53	5150	35750	39	.02	.02	.02	.04	.03	.03	2.98	2.73	2.84	.58	.55	.56	.23	.23	.23
54	5050	35650	39	1.41	1.39	1.40	1.35	1.51	1.43	79.71	73.14	76.43	23.03	22.19	22.56	6.79	7.37	6.93
55	5150	35650	39	.43	.41	.42	9.65	9.67	9.65	36.33	33.28	34.69	8.10	7.72	7.90	2.99	3.06	2.98
56	4900	35500	154	.06	.06	.06	.08	.07	.07	6.67	6.10	6.36	1.23	1.15	1.19	.47	.46	.46
57	5050	35550	39	.35	.34	.35	6.66	6.66	6.65	46.10	42.82	44.27	8.60	8.18	8.37	11.41	11.38	11.36
58	5150	35550	39	.21	.21	.21	.23	.23	.23	16.84	15.42	16.05	3.83	3.63	3.72	1.29	1.31	1.28
59	5050	35450	39	.11	.11	.11	.17	.16	.16	13.17	12.05	12.55	2.41	2.23	2.31	1.13	1.06	1.09
60	5150	35450	39	.04	.04	.04	.05	.05	.05	2.68	2.45	2.55	.73	.69	.71	.26	.26	.25
61	5400	35600	618	.08	.08	.08	.45	.44	.44	8.82	8.07	8.40	1.62	1.51	1.56	.69	.66	.67
62	5800	35600	618	.06	.06	.06	.16	.16	.16	3.73	3.47	3.59	1.21	1.17	1.19	.39	.39	.39
63	6400	35800	2471	.16	.16	.16	.41	.61	.56	12.25	11.30	11.72	3.01	2.87	2.93	2.20	2.17	2.17
64	4000	35400	2471	.08	.08	.08	.11	.10	.10	7.93	7.25	7.55	1.57	1.46	1.51	.69	.66	.67
65	4800	35000	2471	.26	.25	.26	.53	.52	.52	25.06	23.01	23.92	5.34	5.02	5.17	2.25	2.16	2.18
66	5600	35000	2471	.40	.41	.40	.87	.86	.86	34.74	31.96	33.19	7.92	7.49	7.68	5.17	5.07	5.08
67	6400	35000	2471	1520.00	1520.00	1520.00	.94	1.09	1.05	31.02	28.61	29.68	7.64	7.26	7.50	2.92	2.85	2.76

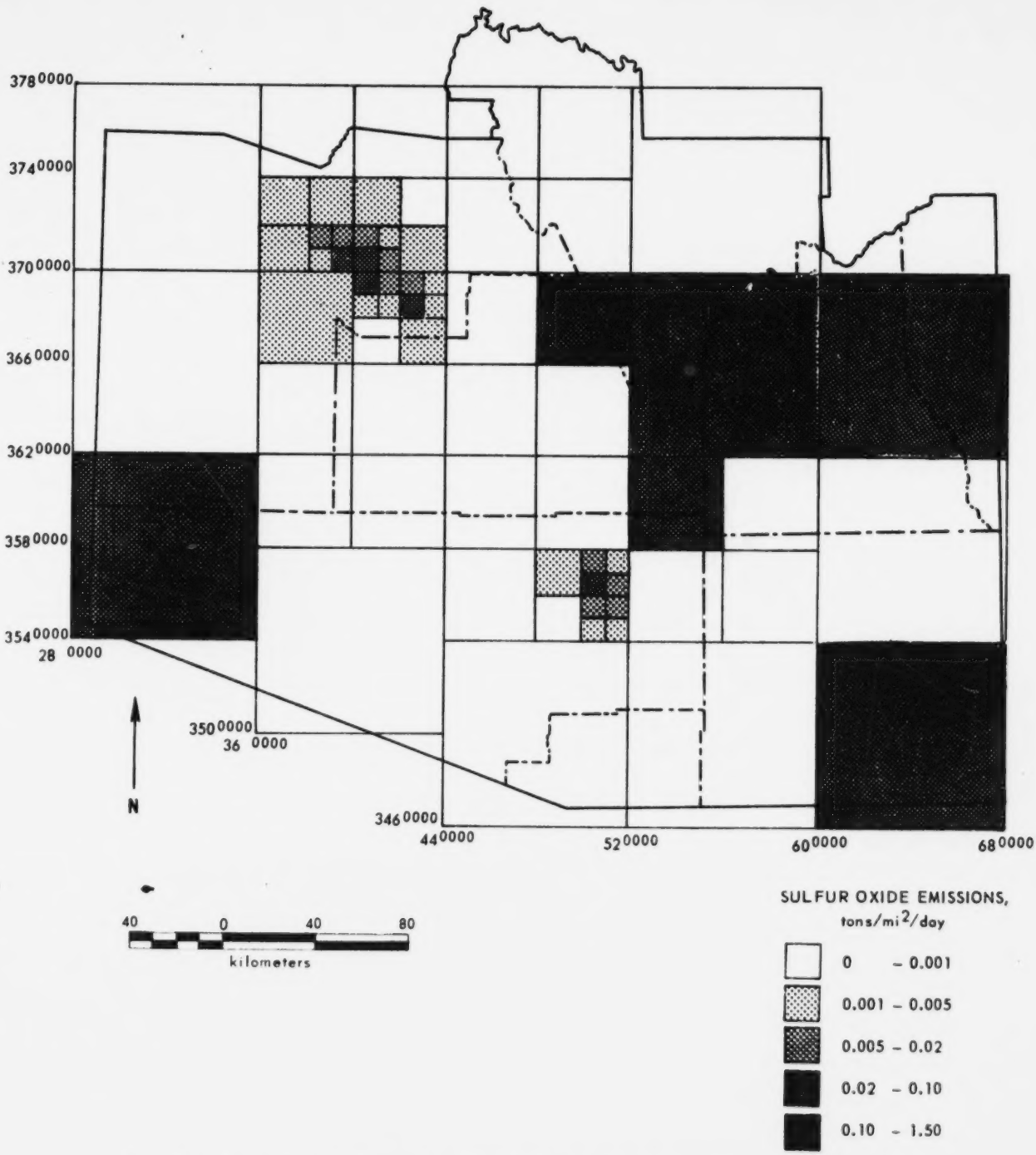

Figure 4. Sulfur oxide emission density map of the Phoenix-Tucson area, 1967.

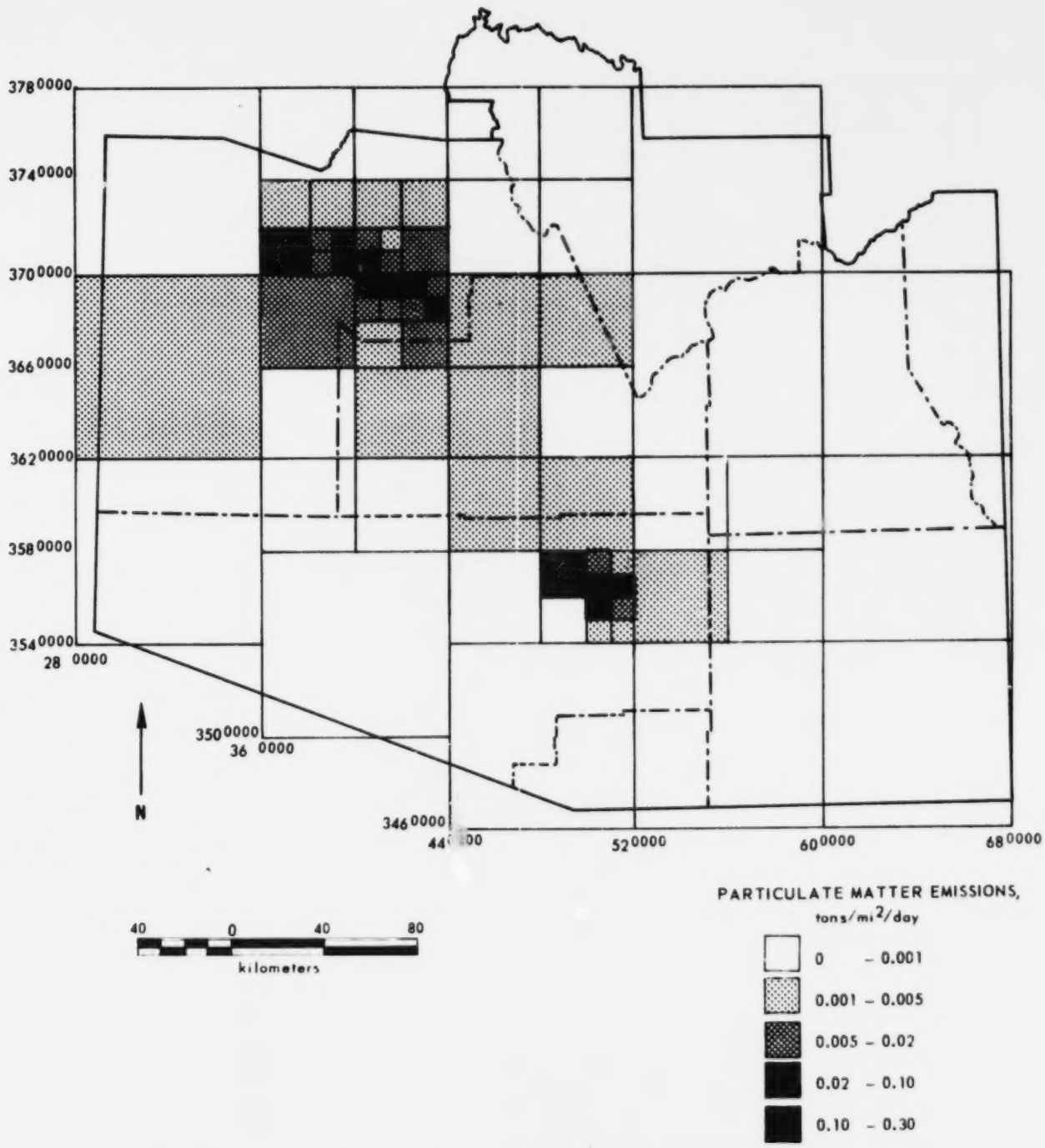

Figure 5. Particulate matter emission density map of the Phoenix-Tucson area, 1967.

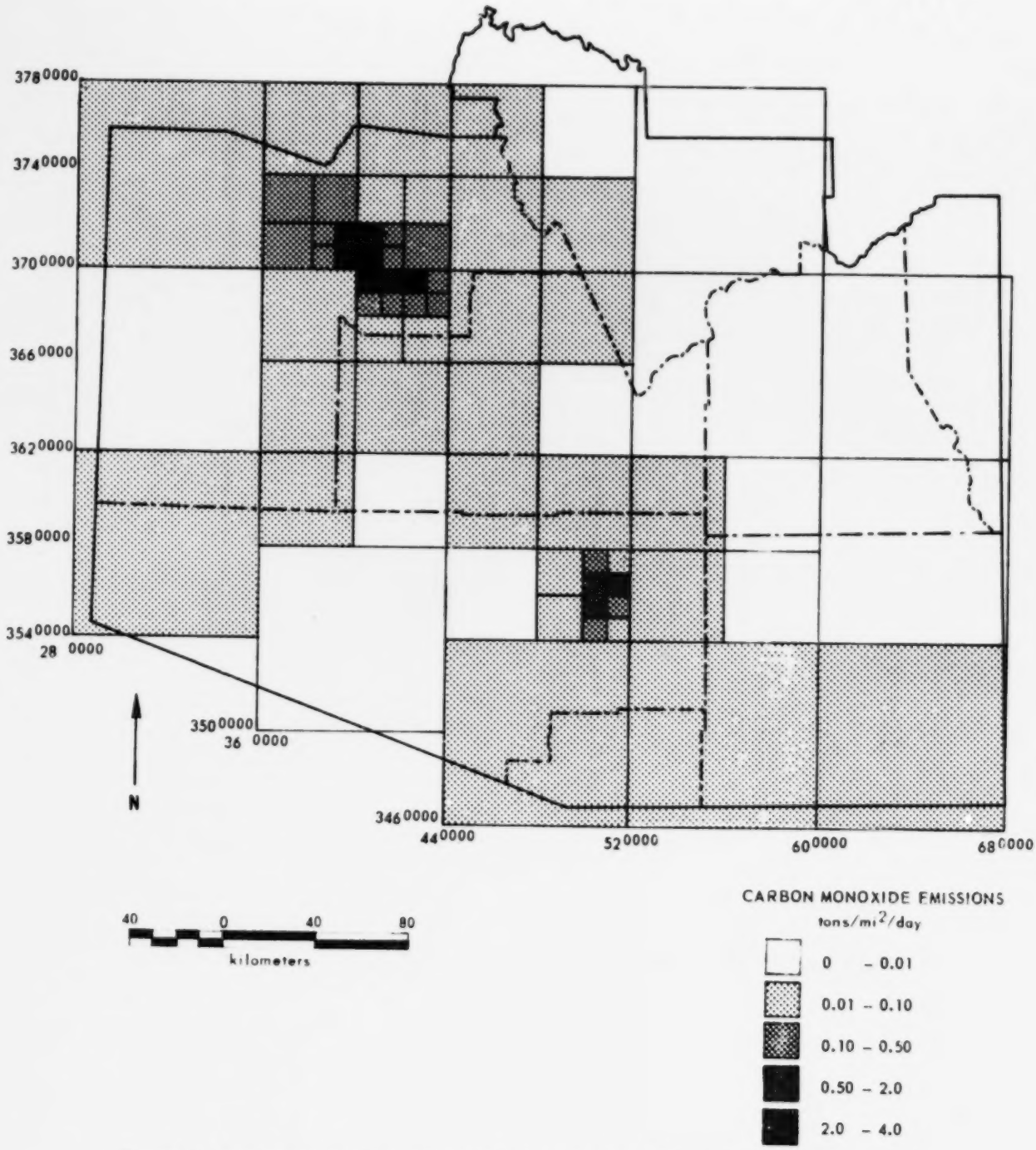

Figure 6. Carbon monoxide emission density map of the Phoenix-Tucson area, 1967.

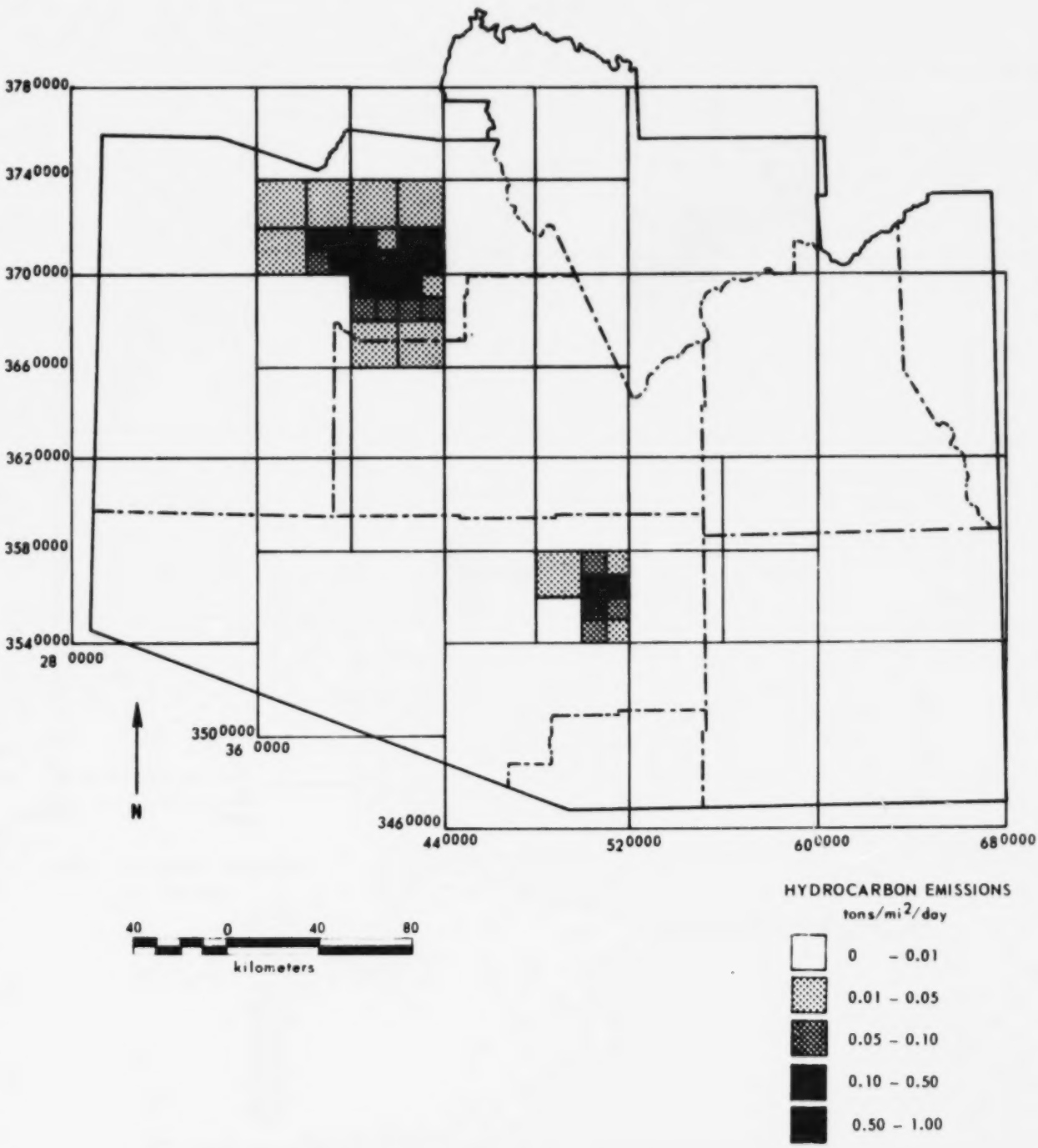

Figure 7. Hydrocarbon emission density map of the Phoenix-Tucson area, 1967.

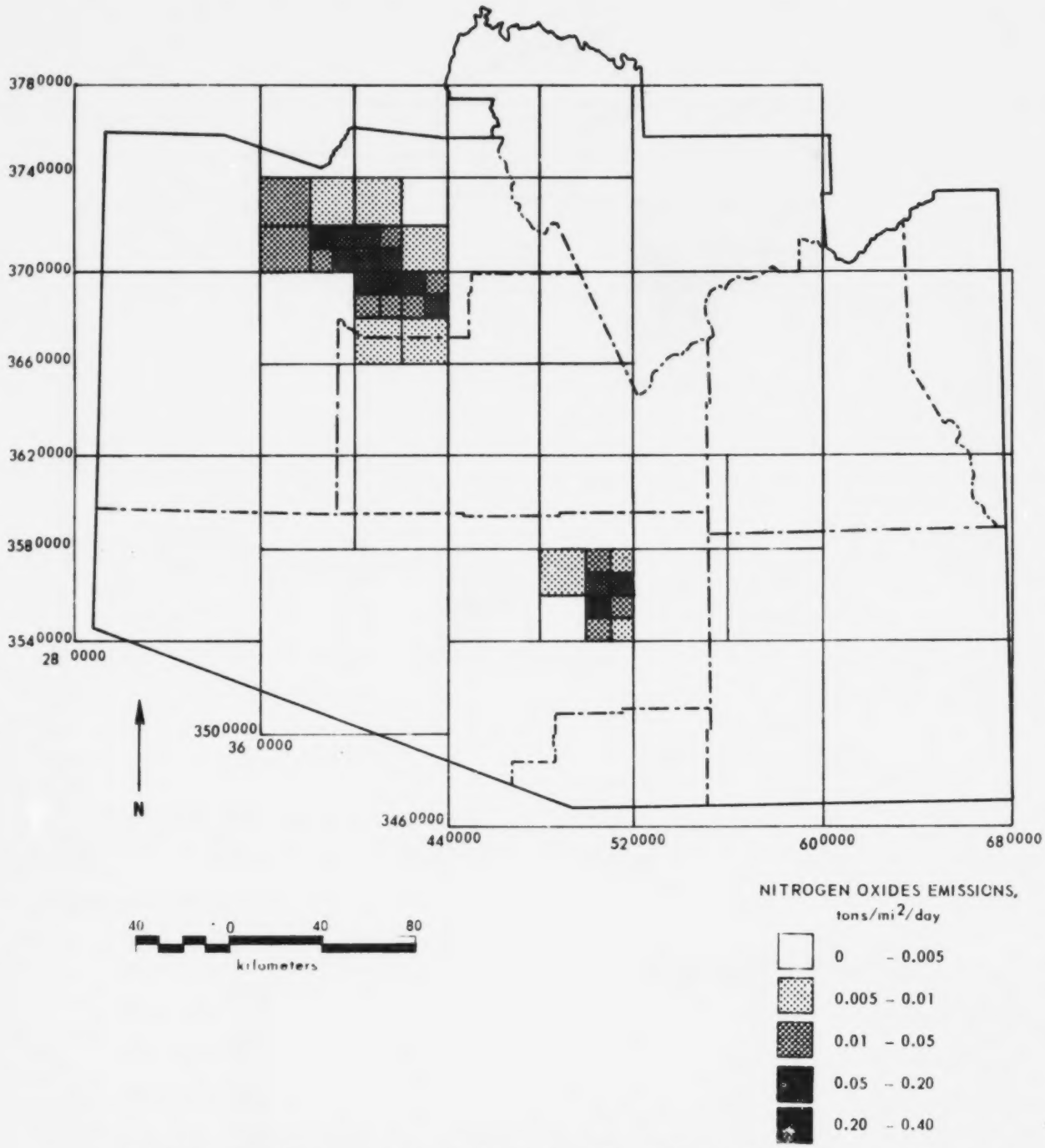

Figure 8. Nitrogen oxides emission density map of the Phoenix-Tucson area, 1967.

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